Inaugural Experimental Dissertation,

BEING

AN ENDEAVOUR TO ASCERTAIN

THE

MORBID EFFECTS OF CARBONIC ACID GAS, OR FIXED AIR,

ON

HEALTHY ANIMALS,

AND THE

Manner in which they are produced;

WHICH, UNDER THE DIRECTION OF

THE REV. JOHN EWING, D.D.

PROVOST OF THE UNIVERSITY OF PENNSYLVANIA,

BY

THE AUTHORITY OF THE BOARD OF TRUSTEES, AND WITH THE APPROBATION OF THE FACULTY,

IS SUBMITTED TO

THE CANDID EXAMINATION OF THE LEARNED;

19th DAY OF MAY, 1794;

For the Degree of Doctor in Medicine.

By WILLIAM BACHE, A. M. OF PHILADELPHIA,

HONORARY MEMBER AND ANNUAL PRESIDENT OF THE PHILADELPHIA CHEMICAL SOCIETY, AND HONORARY MEMBER OF THE AMERICAN AND PHILADELPHIA MEDICAL SOCIETIES.

" Audite o mentibus æquis
" —— neve hæc noſtris ſpectentur ab annis
" Quæ ferimus. *Virgil.*

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M,DCC,XCIV.

For
Dr James Woodhouse
with the respects of
The Author.

TO

THE MEMORY OF

Andrew Adgate,
Jonathan D. Serjeant,
Daniel Offley, and
Joſeph Inſkeep.

ALSO, TO

Matthew Clarkſon,
Caleb Lownes,
Thomas Wiſtar,
Stephen Girard,
Peter Helm,
Iſrael Iſrael,
John Letchworth,
Samuel Benge,
James Kerr,
James Sharwood,
John Haworth,
James Swaine,
Matthew Carey,
Thomas Savery,
Jacob Whitman,
Henry De Foreſt,
And
John Connelly;—

THE *Philanthropic Committee* appointed by Humanity to mitigate the ſufferings of their fellow citizens in the hour of calamity;

In Teſtimony of gratitude,

As a citizen of Philadelphia,

This *Diſſertation* is inſcribed,

BY THE AUTHOR.

TO

JONATHAN MEREDITH,

OF PHILADELPHIA.

PERMIT me, Sir, thus publicly to acknowledge the many acts of friendship for which I am indebted to you, and which were conferred through that benevolence which has always designated itself in your disposition, whether as a Father, Brother, or Friend.

Believe me to be,

With the sincerest Esteem,

Your Obliged Friend,

WILLIAM BACHE.

INTRODUCTION.

PROBATIONARY Theſes have long ſince been the eſtabliſhed heralds to medical honors, theſe appendages to a medical education, whether the vehicles for diſcoveries, or dull repetitions of former knowledge, are too often regarded as juſt and certain criterea of the graduate's merit, the circumſtances attending their production ſeldom being known, and never conſidered.

NOTWITHSTANDING the diſadvantages under which the unexperienced ſtudent labors, ambition would lead him to attempt the inveſtigation of ſome novel ſubject, did

not the enervating dictates of fear or falſe ſhame coldly point out a beaten track and lay before him the dangerous conſequences of aſpiring too much, leſt a failure in the endeavour ſhould inevitably draw down upon his undefended head, the juſt though piercing ſhafts of criticiſm. In this dilemma he finds a difficulty in proceeding. The imputation of raſhneſs on the one hand, ſternly knits its threatening brow; whilſt, on the other, foul repetition caſts a galling ſneer and chills him to the ſoul. The dangers of the former may poſſibly be avoided; but thoſe of the latter are inevitable.

With theſe impreſſions, I have choſen for the following diſſertation, a ſubject, which has not hitherto met with a thorough inveſtigation, and which is of the utmoſt importance not only to the medical character, but to men of humanity in general.

The exiſtence of *noxious vapours*, diſengaged from various ſubſtances has been long ſince known, but it was left for the united labors of a Black, a Prieſtley, and a Lavoiſier, to

to aſcertain their chemical properties, by their truly ingenious and intereſting experiments.

One of theſe, *carbonic acid gas*, in various forms, has oftentimes proven deſtructive to man as well as other animals; and, it has long been problematical amongſt phyſiologiſts whether this gas produced its morbid effects, by any *inherent poſitive action*, or whether it acted only negatively and brought on death, *mechanically*, by excluding reſpirable air.

Some recent phyſiologiſts, particularly Goodwyn and Coleman, have imagined, that the ſuſpenſion of vital action, from the noxious effects of the different gaſeous fluids, was to be attributed to the ſame cauſe as that produced by ſubmerſion in water. The extreme plauſibility of Dr Goodwyn's doctrine concerning the operation of fixed air,* appears to be ſufficient teſtimony againſt its poſſeſſing,

* Dr Goodwyn, page 66, aſſerts that fixed air may be breathed in conſiderable quantities, provided it is mixed with atmoſpheric air.

poſſeſſing, virtually, any deleterious properties, and the abſtract reaſoning adduced by Coleman,* tends directly to eſtabliſh, that it can exert none, immediately on thoſe organs, even did it poſſeſs any.

THE contradictory opinions of theſe two eminent phyſiologiſts, relative to the immediate cauſe of death from drowning, and ſubmerſion in noxious airs, was an additional inducement for me to purſue the ſubject, directing my endeavours, more eſpecially to thoſe points, to which they had bent the leaſt attention, and prompting me to follow up the inveſtigation, as little connected as poſſible with the hypotheſis of either, differing from each only where thorough conviction has rendered it abſolutely neceſſary.

WHATEVER may be the fact, the knowledge of the action of this aëriform fluid, neceſſarily involves much practical good. If it is eſtabliſhed that its operation is purely negative, then it is obvious, that our principal

* See his introduction, page 13, &c.

cipal exertions ſhould be immediately directed to the moſt ſpeedy and effectual means of conveying the ſufferer from its influence; but if on the contrary, it is uncontrovertibly decided, that its action is poſitive and direct, not only the indication neceſſary in the former caſe, but thoſe remedies which promiſe moſt fairly to counteract effectually its letheferous effects, will be loudly called for.

I AM happy, that, in the courſe of the following enquiry, facts have ſo opened upon me, as to induce an entire revolution in my ſentiments reſpecting this action, inaſmuch as it precludes the leaſt grounds of the imputation, that I have been biaſſed by preconceived hypotheſes, and therefore, have viewed the ſubject only with a jaundiced eye; and here I conincide in opinion with a celebrated profeſſor, who is remarkable for his numerous and willing ſacrifices of prejudice to the unerring dictates of truth and reaſon.

THE diſagreeable neceſſity of inflicting death on ſo many animals, at firſt rendered the ſubject extremely irkſome; but when I reflected

reflected that these immolations were absolutely necessary to a thorough investigation, and that myriads were daily slaughtered, not only to satisfy the rapacious demands of nature, but to delight the pampered appetite of the epicure, I was induced to suppress those feelings, as I was not prompted by idle curiosity, but was sacrificing at the shrine of humanity.

SEC-

SECTION I.

What are the effects of submersion in carbonic acid gas on animal life?

IN every investigation, and more especially in experimental researches, that method is to be adopted which will comprehend primarily the most obvious traits of the subject, leaving the more intricate and less established facts, for subsequent consideration.

THE most prominent features of the present inquiry are, the state of the animal, vital, and natural functions during the time of submersion in carbonic acid gas, the appearances of the body after death, upon dissection, and the manner in which the gas must be applied to produce these phænomena.

1. *The*

1. *The appearances during the life of the animal.*

When first the animal is immersed in fixed air, he makes forcible exertions to relieve himself, but almost immediately becomes apparently stupid, and so much under the effects of debility, that he lays down as if asleep, or rather in an apoplectic fit; all voluntary motion is then greatly diminished and disordered, and sensation is so far impaired, that the animal will patiently suffer to be pinched without appearing to feel any uneasiness*, and the natural heat of the body is somewhat increased† and continues so for a

* This is further evinced from an accident which is related, to have happened to L'Abbé Briquet de Lavaux, by M. Banau, M. D. In transporting him from the place infected with the vapours of charcoal he says, "Ce "transport se fit avec tant de précipitation, que nous pous- "sâmes violemment M. L'Abbé Briquet contre une porte "vitrée: un carreau de vitre qui en fut cassé, fit deux "profondes blessures que notre suffoqué ne sentit point, "ce qui prouve qu'en pareil cas on ne doit point regar- "der l'insensibilité comme un signe de mort," as he recovered. Journ. de Ros. an. 1774, vol. 2. p. 464.

† Portal observes,—"Les corps des personnes suffo- "quées par des vapeurs mephitiques conservent long-temps "leur

ſhort time. The pulſations of the crural artery of a dog are not to be felt before ſubmerſion, without particular attention, but when the reſpiration becomes affected, the pulſe ſuffers a conſiderable change. Slight convulſions ſucceed over the whole body, and particularly about the ſphincter ani. Sometimes a vomiting occurs; but more frequently a copious diſcharge of urine and fæces. A ſhort time, however, before theſe occurrences, the reſpiration from being carried on without much labour, is conſiderably accelerated, and becomes ſo difficult, at laſt, that the muſcles of the abdomen and thorax take on a violent action, when the mouth, together with the noſtrils, become diſtended.

With this affection of the reſpiration, the ſtate of the pulſe as has been already hinted at

experiences

" leur chaleur; elle eſt même quelques fois plus forte im-
" mediatement apres la mort que pendant la vie et *que dans*
" *la parfaite ſanté*——mais nous en ſommes convaincus
" principalement dans quatre perſonnes mortes ſuffoquées,
" trois par la vapeur du charbon et la quatrieme par la
" vapeur du vin qui fermentoit."

experiences a conſiderable revolution. From being nearly natural, and ſcarcely to be diſcerned, it is now plainly to be felt and becomes tenſe and violent, and, as the reſpiration advances to its achme, the pulſe increaſes in ſtrength and impetuoſity. This ſtate of the pulſe is happily deſcribed, by M. Troja, in the following words; "A "meſure que la reſpiration devenoit encore "plus forte et plus genée, les pulſations de-"venoient auſſi plus impetueuſes; il ſem-"bloit que ce fut une injection de mercure "pouſſée avec la plus grande force*."

SHORTLY before death the reſpiration ſuffers another change; whilſt it becomes ſtill more difficult, its frequency, as well as fullneſs, ſuffers a conſiderable diminution, the intervals between the inſpirations becoming great, and the quickneſs much augmented; at this time, upon the whole, each inſpiration appears more like a convulſive motion, than a natural effort to draw in air. The pulſe gradually becomes weaker, and very intermittent,

* See his eſſay on fixed air, in Obſervations ſur la Phyſique, &c. par M. L'Abbé Roſier, vol. 1. 1778.

intermittent, and during the ſhort period of each inſpiration its oſcillations are very frequent; but when the ſtate of expiration has commenced they are more ſlow and feeble. The air now enters the lungs in ſmaller quantities during every exertion to inſpire, which diminiſh gradually in their force; partial ſhiverings of the limbs ſupervene; the tongue of the animal is generally protruded, the pulſation of the artery fails entirely, the heart vibrates, or rather appears to thrill feebly; its action ceaſes and the animal expires almoſt inſtantaneouſly.

It is extremely difficult to aſcertain, a priori, the time that an animal will exiſt in carbonic acid gas, and I believe that there is no ſubject in phyſiology ſo undeterminate, as variations in the reſults may ariſe from four cauſes.

1*ſtly*, From the age of the animal. Young animals are ſuppoſed to reſiſt the baneful influence of carbonic acid gas, longer than adults.

2*dly*,

2*dly*, From the ſpecies. Inſects and cold blooded animals are ſaid to live longer than quadrupeds, and theſe longer than birds *.

3*dly*, From the different degree of irritability in the ſame ſpecies of animal, of the ſame age.

4*thly*, FROM the different degrees in the purity of the air, as to the adventitious mixture of various gaſes and effluviæ †.

THE viſage and neck of animals periſhing in fixed air is much ſwollen, and the faces of men who were affected with the ſame gas are ſaid to be livid ‡. The body remains pliant for ſome time after death, but at length becomes rigid, the limbs remaining ſtiff.

2. Phæ-

* There are however a variety of opinions on this ſubject. See Portal, Troja—Journal de Roſier.

† As the detail of ſymptoms related above may appear ſtrange to thoſe who have only obſerved the ſudden effects of pure carbonic gas, it is neceſſary to obſerve, that the experiments from which they are adduced were performed in gas of various purity, and ſeldom without ſome proportion of vital air.

‡ See Portal.

2. *Phænomena on Diſſection.*

UPON opening the thorax, the heart preſented itſelf ſo diſtended with blood as entirely to fill up the whole cavity of the pericardium. The right auricle, ventricle, and both the cavæ, together with the pulmonary arteries, were completely diſtended with blood. The left auricle, ventricle, and pulmonary veins, not ſo much diſtended with blood as the right, but never more than half empty. The aorta generally void of blood, or, at moſt, containing a very ſlender portion of that fluid*.

THE lungs always appeared covered, more or leſs with livid blotches†, occaſioned, I imagine by the extravaſation of blood, as they became perfectly florid, and nearly the colour of arterial blood, after the lungs had been repeatedly inflated ‡.

ON

*In frogs, the heart was generally found entirely empty when the animal was completely dead.

†Troja and Haller mention the ſame appearances.

‡Is there any circumſtance in the mechaniſm of the lungs, adapted to accelerate the union of vital air with the blood?

On opening the abdomen, the liver and ſpleen were found diſtended with blood; upon the liver, in two caſes, I obſerved a few ſpots; whilſt the ſpleen was covered with many, particularly around the edges. The cava deſcendens, the veins of the inteſtines, and kidneys appeared as if they had been injected.

In thoſe caſes in which I opened the cranium, the brain exhibited no remarkable appearances of a diſeaſed ſtate. The venous ſinuſes were ſomewhat diſtended with blood, the veins of the brain, little more diſtended than natural, and the arteries nearly empty. The ventricles of the brain were either found empty, or contained but a very ſmall quantity of lymph. The blood found in the different cavities of the body and veſſels

blood? I imagine this to be the fact, for I have repeatedly obſerved that the black blood in the lungs of thoſe animals which have been deſtroyed by carbonic acid gas, became florid much more rapidly than that which was poured out into the thorax, by the rupture of the pulmonary veſſels, &c. in detaching the lungs from the heart, though it was equally expoſed to the action of the atmoſpheric air.

veſſels of the brain was uniformly of a darker colour than natural.

In what manner muſt carbonic acid gas be applied to the body, to produce its baneful effects?

Does it cauſe ſuſpenſion of vital action, and laſtly death, by its operation on the external ſurface of the body?

Does it affect the glottis ſo as to obſtruct inſpiration?

Or does it enter the cavity of the lungs themſelves, and by that means, produce its deleterious effects?

The following experiment related by Dr Wiſtar in his anatomical lectures, proves that its operation upon the external ſurface of the body merely is not ſufficient to account for the phænomena.

A curved tube was applied, to the trachea arteria of an animal, into which an inciſion

ciſion had been made; ſo that no air could paſs into the lungs but through its medium. The animal was then immerſed in a veſſel containing carbonic acid gas; it remained in this ſituation for ſome time, with very little inconvenience, whilſt the bore of the tube communicated freely with the open air; but when the experiment was reverſed, and the opening of the tube plunged into a veſſel containing fixed air, the animal ſhortly expired *.

This point being determined we are next to enquire into the manner of its application to the organs of reſpiration.

Coleman,

* I repeated this experiment on a pigeon, by ſecuring a ſilver tube in the trachea, and immerſing the body and head under an atmoſphere of fixed air, whilſt the canula communicated with the atmoſphere. It remained in this ſituation twelve minutes, its reſpiration was not affected more than before immerſion, but it ſhewed ſome ſigns of irritation and uneaſineſs from the action of the air upon the ſchniderian membrane, to which it had acceſs. After this, I reverſed the experiment, by removing the body and head from the fixed air and immerſing the end of the tube into a veſſel containing that gas, the animal immediately expired.

COLEMAN, as has been before obſerved, is of opinion, that its true mode of action is by irritating the glottis to ſuch a degree as to cauſe a conſtriction, which is ſo great as to impede the entrance of the external air, whilſt that which remains in the lungs from the laſt inſpiration may be forced out, cauſing a collapſe of thoſe organs, totally impeding the circulation of blood through them. Not aware, however, that the ſame objections, which he has ſo laviſhly offered to others, may with great propriety be applied to himſelf, he has attempted to explain, and account for the operation of noxious airs in general agreeably to his theory of collapſe. In objecting to the hypotheſis of others, on this ſubject, as not being ſupported by "*argument*, *experiment*, or *analogy*," he has entirely forgotten that his arguments, experiments and analogies are not fraught with more ſatisfaction on the ſubject than thoſe of his antagoniſts*.

INGENIOUS, however, as the ſpeculations of all parties may appear, ſtill an experiment

 was

* See Coleman, p. 19, &c.

was wanting to determine the fact, whether carbonic acid gas entered the lungs or not. It appeared to me probable, that if a tube could be ſo applied to the head of an animal, as to admit thro' its bore, a free paſſage of air which might be contained under a receiver, entirely excluding the entrance of any external air, the wiſhed-for end would be obtained.

By repeated ligatures I fixed a curved tube to the end of a bladder, oppoſite to the neck, and made a perforation in it over the bore of the tube ſufficiently large to admit a free paſſage of air through it. I then enlarged the neck of the bladder that it might paſs eaſily over the head of a dog, and with a drawing ſtring ſecured it round the neck. I then paſſed a broad ſtrip of linen ſeveral times round this end of the bladder, ſufficiently tight to obſtruct the paſſage of the external air between the bladder and the neck, taking care to impede the circulation in the neck as little as poſſible. To be convinced that the ligatures alone would not cauſe immediate death, and thereby fruſtrate the intention of

the

the experiment, I ſuffered him to remain in this ſituation ſome time, and obſerved little inconvenience but what might be expected to ariſe from breathing through ſo ſmall an aperture as the bore of the tube.

HAVING taken theſe precautions, I proceeded to introduce the diſengaged extremity of the ſyphon under a receiver containing a quantity of fixed air, and could obſerve by the riſing and falling of the water in the receiver, that the animal breathed; he died in ſix minutes, the carbonic acid gas being mixed with a portion of oxygenous gas.*

I ALSO invariably obſerved a motion of the thorax and muſcles of the abdomen in every quadruped that was expoſed to the fixed air. Thus it appears that fixed air does enter the lungs, and that its ſphere of action, if not confined to, is ſolely directed through, the medium of their cavity. †

* I repeated this experiment with pure carbonic acid gas, and found that the animal breathed it equally as in this inſtance.

† I alſo obſerved that expanſion and contraction took place in the lungs of frogs, when expoſed both to the at-

THE particular mode of operation will be the ſubject of the ſubſequent ſection.

SECTION II.

Whether does carbonic acid gas produce its effects, indirectly by mechanically excluding atmoſpheric air from the lungs, or directly by an inherent operation in thoſe organs?

THIS very intereſting part of our enquiry is by far the moſt intricate, as it has hitherto been but little attended to by authors; who have merely contented themſelves, as it were, with half proofs and analogies, throwing but little light upon the ſubject through the unerring channel of experiment.

VARIOUS doctrines have been advanced at different periods to explain the phænomena produced by noxious airs, correſponding generally

moſpheric, as well as carbonic acid air, whoſe abdomen and thorax were laid open by a crucical inciſion.

generally with the then exiſting ſtate of chemical knowledge, and have fluctuated continually with the rapid advances made in the ſpeculative branch of that ſcience.

WHILST, in the earlier ages of chemical reſearches, it was the opinion of many that carbonic acid air proved deleterious from a defect of an elaſticity,* which was ſuppoſed to be the only neceſſary quality in air for the proceſs of reſpiration; others on the contrary imagined, that the ſame effects were produced by an exceſſive degree of that elaſticity.† The former idea was ſoon proven to be erroneous, inaſmuch as it was found that fixed air was as capable of filling up ſpace, and as ſubject to the laws of expanſion as any one of the elaſtic aëriform fluids, and the latter hypotheſis was rejected when the nature of gaſeous fluids became better to be underſtood.

THESE opinions were ſhortly ſucceeded by the idea that death or ſuſpended vital action

* See Hale's Vegetable Statics, p. 260—1.

† See Fontana on Poiſons, Vol. I. p. 90. Morgagni, Epiſt. 19. art 39. Portal. Journ. de Roſier.

action was induced by ſuffocation. Hoffman expreſſes himſelf to this end in the following forcible terms.* " Eadem enim horum ope-
" randi ratio eſt, ac ſi aſperam arteriam filo
" conſtringas; nam utroque horum aëris ſuf-
" ficiens introitus impeditur."† Morgagni conſiders alſo the operation of noxious vapors to be ſimilar to ſuffocation, which he imagines produces death by cauſing a ceſſation of the due circulation in the lungs.‡ This idea has been ſince modified, and it has been imagined that all the morbid effects were

* Hoffman, Tom. 4. and as quoted by Percival, p. 99.

† Hoffman appears to have had various ſentiments on the ſubject, as may be obſerved by comparing the following paſſage with that above quoted. " Vapor igitur
" tam tenuis et ſubtilis, in aërem evectus ibique concluſus utique medianti inſpiratione per nares in caput, et
" per aſperam arteriam admiſſus in pulmones, propter
" ſummam ſuam tenuitatem partium ſolidarum vaſorumque poris ſeſe interne inſinuat, inque minimos nervorum,
" cerebræ et meningum poros penetrat; ubi illud fluidum ſubtiliſſimum, quod ſenſibus et motibus præeſt; inquinando actiones ſic dictas animales ſubito perturbare
" atque invertere valet. Accedit, quod aër etiam, copia
" horum vaporum imbutus, de vi ſua elaſtica expanſiva
" in expandendis vaſis et veſiculis pulmonalibus multum
" amittat." Hof. Tom. 4.

‡ Morgagni, Epiſt. 19. art 39.

were produced by an irritation on the nerves of the bronchiæ, and an univerſal conſtriction of the air-veſſels of the lungs themſelves*.

Since that time from the analogy between ſome of the effects of carbonic acid gas on the nervous ſyſtem, and the operation of certain ſtimuli on that ſyſtem, it was held by ſome† that carbonic acid gas, entering the lungs in large quantities, by its exceſſive ſtimulating power, acted primarily upon the brain and nervous ſyſtem, deſtroying thereby the action of the moving powers, and with them all vital motion; and by others, that this ſame ſtimulant power produced its morbid effects by immediately deſtroying the irritability of the heart, being analogous in its operation to electricity ‡.

When by the labours of Prieſtley the doctrine of airs began to evolve her variegated wings, from the clouds of obſcurity by which it

* Fontana on Poiſons, vol. I. p. 95.

† Percival's Eſſays, p. 101.

‡ Fontana on Poiſons, vol. I. p. 96.

it had been enveloped for ages, these opinions were rejected by some chemical physiologists, and as it was imagined by them, that the efficient cause of respiration was to disengage phlogistic vapours from the lungs, and that respirable air as having an affinity for them, was by that means fitted for that function, so they explained the action of carbonic acid gas on the lungs according to this theory, and taught that by permitting the accumulation of these vapours in the lungs it was negatively noxious*.

In the year 1788 two writers †, of distinguished talents for physiological investigation entered the lists, and endeavoured to account for the phænomena produced by noxious gases, according to preconceived hypotheses on the subject of submersion. ‡One taking it for granted that apoplexy was the cause of death in drowning, from analogy supposed the same to be the case here; and §the other pursuing the same train of reasoning advanced as

* Priestley.
† Kite and Godwyn.
‡ Kite.
§ Godwyn.

as a principle, that fixed air acted only mechanically by excluding vital air, and not by any inherent letheferous quality.

In oppoſition to theſe laſt hypotheſes in particular, the doctrine of collapſe was with ſome amendments, anſwering to the improvements in ſcientific knowledge, again revived* by an ingenious phyſiologiſt, and ſuſtained by various new ſupports; of this doctrine as far as it relates to the preſent ſubject, we have already given our ſentiments in the laſt ſection.

We have thus collected the ſentiments of various authors, not with the moſt diſtant idea of entering into a minute detail of the merits of each, but that we might have in one point of view, the different ſentiments which have been ſuggeſted within the preſent century, that they might collectively be compared with that which we ſhall hereafter advance.

It now remains more eſpecially to proceed with the moſt important point in this ſection,

* Coleman.

ſection, *viz.* Whether carbonic acid gas acts mechanically on the lungs by excluding vital air, or whether it poſſeſſes an inherent power over the animal œconomy.

As it has been generally obſerved by authors* that inſects live longer in noxious airs than

* See Troja, Journ. de Roſier, vol. 5. an. 1778. The reſult of his experiments are different from mine, and moſt probably not without an evident cauſe. They point out that flies and other inſects live longer in the fumes of charcoal than cold blooded animals, but it will be found that the reverſe took place with me, for the frogs on which I tried them ſtruggled under the operation of carbonic acid air between ten and fifteen minutes, which is at a medium twenty-five times longer than the flies; however an allowance muſt be made for the difference in the ſtrength of the air made uſe of in the experiments of Troja, and that which I uſed in proſecuting this enquiry; Troja expoſed his animals to the vapors of charcoal, obtained in a very imperfect manner, whereas pure carbonic acid, which was obtained from powdered marble, by means of the vitriolic acid, was the medium in which I operated.

The ſeaſon of the year moſt probably had the greateſt effect in influencing the reſults of the experiments which I have related, as they were made on the frogs immediately at the time of hybernation, and upon the flies ſoon after their migration from that ſtate.

This

than any other claſs of animals; I ſhall firſt begin by obſerving the effects of carbonic acid gas upon them.

This is moſt probably the caſe, for it is to be remarked that plants in autumn are in a ſtate of exhauſtion, during the winter ſeaſon, from the languid action of the different organs, the vital actions appear to be ſuſpended: The natural conſequence of the ſuſpended action of all theſe ſtimuli, as well as that of heat, is the accumulation of irritability or mobility in the plant. When ſpring ſlow returning with its genial warmth, it proves ſalutary to the vegetable kingdom, but if inſtead of the gradual application of heat, ſuited to the ſtate of accumulation in the plant, the ſolar influence is ſuddenly increaſed, violent effects always ſuperſede, and the fruits, if not the plant itſelf, are deſtroyed inevitably. The ſame progreſs may be traced in the animal kingdom. In hybernating animals the effects of the ſummer heat, and the continual exerciſe of the various organs during that ſeaſon, are analogous to thoſe in plants. In the autumn, the capacity of the muſcular ſyſtem for irritability is diminiſhed, by the gradual operation of the ſtimuli above mentioned, and during the time of hybernation the vital powers appear to be ſuſpended. During this time the operation of ſtimuli being remote, the irritability conſequently ſuffers an accumulation, and on the return of ſpring the animal is awakened to new and vigorous action, when all ſtimulating powers, having a greater field of action, will operate with increaſed violence. This idea receives additional ſupport from the obſervations of M. Fontana, who relates, that during the winter

UNDER a receiver filled with fixed air, obtained from powdered marble and the vitriolic acid diluted with water, I introduced ſeveral flies. Immediately upon their firſt entrance they ſtruggled, but in a few ſeconds their limbs were affected with tremors and contracted, and they all became motionleſs in the ſpace of forty ſeconds, and ſome in leſs than thirty. I then removed them from under the receiver, and without paying much regard to them, after I had ſubjected them to ſtrict ſcrutiny, to obſerve if any viſible ſigns of motion or life remained, I threw them into a veſſel containing the water by means of which the air had been collected and retained in the receiver.

RETURNING

winter ſeaſon, vipers which he had kept for his experiments, remained in a torpid ſtate, though the thermometer was at 59°, and when he endeavoured to render them vigorous by warmth, and expoſed them to a heat of 67 degrees only, in two minutes they ſunk under its ſtimulating influence, though in ſummer after the irritability had ſuffered a gradual diminution, by a ſlow and ſteady increaſe of heat, and the continued action of the vital organs, they can withſtand its operation to a much greater degree.

Returning to the veſſel in the ſpace of an hour, to repeat the ſame experiment with freſh caught flies, I obſerved ſome of thoſe which I had before thrown in, ſo far recovered as to ſwim about the ſurface of the water, many of them, however, did not experience the ſame ſalutary effects although they had been expoſed no longer to the air, and had been ſubjected to the ſame treatment with thoſe which recovered. Upon comparing the reſults of many experiments made at that time, I found that flies continued to ſhow ſymptoms of life when immerſed in carbonic acid gas, from between twenty five to forty ſeconds. It may be well to mention in this place, an extraordinary change of colour which took place in the eyes of many flies, the ſubjects of theſe experiments; I was firſt ſtruck with a beautiful redneſs of the eyes of a fly which had periſhed in carbonic acid gas, but could not poſitively determine whether it was cauſed by the air or was natural; after this, however, I repeatedly examined their eyes, previous to immerſion, and generally found them of a dark mahogany colour, and ſeveral times this red or rather co-

quelicot

quelicot appearance of the eyes took place after fubmerſion in the acid gas, though if the animal recovered, it very ſoon diſappeared, and upon a ſecond immerſion, this red colour was not ſo ſtrongly marked.

WHENCE did this alteration in colour originate?

DID the weakneſs of the coquelicot colour ariſing from a ſecond application of the carbonic acid gas, proceed from the effects of habit?

WISHING to try if effects, ſimilar to thoſe already enumerated, would be produced by merely excluding vital air from the lungs, I immerſed, at the ſame time many flies under an inverted receiver completely filled with water,* thereby cutting off all means of acceſs to the external air, and found that far from dying in ſo ſhort a time as thoſe expoſed to fixed air, they continued to move from

* Flies immerſed under a receiver, containing inflammable air, lived generally as long as thoſe immerſed in water.

from between fifteen to twenty minutes.* By theſe comparative experiments, it is evident that the mere excluſion of atmoſpheric air, is not ſufficient of itſelf to produce the violent and ſudden effects which are the reſult of ſubmerſion in carbonic acid gas, on flies, ſpiders and probably all other inſects.

THE experiments which were inſtituted on frogs, perfectly coincided with thoſe above related, though in ſome inſtances the manner of applying the carbonic acid gas was in a degree varied.

IT has been before remarked, that Goodwyn was of opinion that fixed air would not exhibit any noxious phænomena on living animals, when mixed with a due proportion of vital air, and hence he naturally concluded, that it poſſeſſed no inherent deleterious properties. The experiments above related, however, clearly evince that this concluſion has not been deduced from data ſufficiently eſtabliſhed,

* Spiders were evidently affected in the ſame manner as flies.

eſtabliſhed, and thoſe which I am about to relate as made on amphibiæ, directly coincide in ſtrenghtening this opinion.

If an animal is expoſed to a given quantity of atmoſpheric air, ſuppoſe 25 oz. and another in ſimilar circumſtances to an artifical atmoſphere,* compoſed of carbonic acid gas, inſtead of the azotic gas with the due proportion of vital air, the whole amounting to 25 oz., the reſult will determine whether or not the aëriform carbonic acid poſſeſſes any hurtful power.

On Wedneſday the twenty-ninth of October, I immerſed a frog under an inverted receiver

* This idea of conſtituting an artificial atmoſphere, I firſt learnt from Dr Wiſtar in a converſation I had with him on the ſubject. I afterwards met with it in a treatiſe on dephlogiſticated air, by Count Morozzo, who ſays. "Après avoir obſervé que la reſpiration des animaux mephitiſe tres peu le gas dephlogiſtiqué, et que l'on parvient à lui rendre ſa première bonté, j'ai éprouvé d'agréger le meme gaz avec tous les gaz meurtriers, et avec l'air vicié par les differens procédés phlogiſticans, pour obſerver s'il auroit la propriété de leur oter la qualité meurtrière et de les rendre reſpirables." Journ. de Roſ. Ann. 1784, Vol. II. p. 113.

ceiver filled with an artificial atmoſphere, compoſed of ſeven ounces of vital air, and eighteen of carbonic acid gas, making the compound in the proportion of twenty-eight parts of vital air in the hundred, the quantity of that gas aſcertained to exiſt in the atmoſpheric compound.

At the ſame time I confined another frog in twenty-five ounce meaſures of atmoſpheric air, this being neceſſary as a ſtandard of compariſon.

The frog which was placed in the factitious atmoſphere was taken out perfectly dead intwo hours and thirty-five minutes. On removing the ſternum, the lungs were found partly diſtended, the heart entirely void of blood, and deprived totally of irritability.

The frog which had been confined in the atmoſpheric air remained in that ſituation eighteen hours without having ſuffered much apparent uneaſineſs or inconvenience.

Not having any thing of the nature of an eudiometer whereby I could poſſibly aſcer-

tain with any degree of preciſion the purity of the vital air uſed in the foregoing experiment, and not being perfectly ſatisfied that it might not have influenced the experiment, and accelerated the death of the frog by ſome noxious impurity, I determined to try what effect the pure oxygenous gas alone would have on frogs, endeavouring in this way to detect any hurtful matter that it might be impregnated with.

I IMMERSED, therefore, a frog under a receiver containing ſeven ounce meaſures of vital air, obtained at the ſame time with the former, (from the black calx of manganeſe by means of concentrated vitriolic acid), and whilſt I remained obſerving him, which was for ſeveral hours, I obſerved no change to take place in him except that his reſpiration was rendered more ſlow and tranquil than before ſubmerſion; after continuing expoſed to the vital air ſixteen hours I permitted him to eſcape, which he did with alacrity, as what I had already ſeen had ſufficiently ſatisfied me of the purity of the vital air which had been uſed in theſe two experiments.

RE-

REFLECTING upon the experiments which had been inſtituted, I found that one objection might be advanced againſt the juſtneſs of that which had been tried in the artificial atmoſphere; viz. that the carbonic acid gas had not been accurately mixed with the vital air, and conſequently, retaining, by its gravity, the bottom of the receiver, it would ſurround the frog and thereby exclude entirely the vital air from his lungs. That it will form an aggregate if proper care be taken, cannot be doubted from the following obſervation of M. Fourcroy*; ſpeaking of carbonic acid gas, he ſays, "Il ſe mêle a l'air vital, mais ſans "alteration, et il forme un mêlange que l'on "peut reſpirer pendant quelques tems, pourvu "qu'il n'en faſſe que le tiers."

TO obviate the above objection, the following day I procured a large bottle, and having filled it with water, introduced 7 oz. of vital air, and added to this 18 oz. meaſures of carbonic acid air, then making a mark on the outſide of the bottle correſponding

* Fourcroy Elemens d'Hiſtoire Naturelle, &c. T. 1. p. 440.

ing to the volume of the air in it, and carefully ſecuring the mouth with a ground ſtopper, I agitated the two airs together, thereby producing a complete mixture of them. This agitation conſequently cauſed a conſiderable abſorption of the fixed air, which I ſupplied, knowing what quantity to add, from the mark on the outſide.

At forty minutes after one o'clock, I expoſed a frog to 25 oz. meaſures of atmoſpheric air.

Two minutes after a ſecond frog was put into the factitious atmoſphere, in which it was ſuffered to remain three hours and an half, when it was taken out dead, having been without motion ten minutes before it was removed.

The frog in the atmoſpheric air lived till the noon of the following day when it eſcaped.

These experiments were repeated on frogs ſeveral times, and always with a ſimilar reſult, ſome ſuſtaining the action of the fixed air

air longer than others, generally however from between two and an half to four and an half and five hours.

A FROG was expoſed to an atmoſphere of fixed air alone, he made ſome exertions when firſt ſubmerſed, but ſoon became motionleſs; his thorax moved equably at firſt and without much apparent alteration, but ſoon took on irregular contractions and expanſions, which entirely ceaſed after he had been immerſed eight minutes and an half, when he expired. On opening the thorax and abdomen the heart was found diſtended with a black coloured blood, and was excited into action by the puncture of a lancet, and the lungs were devoid of air. This frog was amongſt many the moſt ſuſceptible of the impreſſions made by carbonic acid gas; others lived thirteen, ſome fifteen minutes before they expired, and in many the lungs were in a great degree diſtended with air.

AT the ſame time, a frog was immerſed under water, which had ſtood ſome time to deprive it of any air which might have been diffuſed

diffuſed through it. It exhibited after ſome time all the phenomena of a drowning animal, but in a moderate degree only, and did not expire until fifty-ſix hours had elapſed*.

THIS

* As it might probably be objected to this experiment, that the frog being amphibious had a power of decompoſing water, and by that means of ſupplying itſelf with a due quantity of oxygene to carry on the various functions of the ſyſtem, to this protracted time, with a degree of regularity, I made a vacuum as to oxygenous gas in two ways; 1. By immerſing them in mercury, and 2. By preparing an atmoſphere of light inflammable air from diluted vitriolic acid and iron filings, by theſe means avoiding even the moſt trifling grounds of ſuſpicion as to the validity of the experiment.

I placed a frog in a veſſel two-thirds full of mercury, and with a ſufficient weight reſtrained him from riſing to the ſurface, to which the gravity of the fluid naturally urged him. After half an hour had elapſed I removed the weight, the frog was ſtill alive but conſiderably injured by the exceſſive preſſure of the mercury.

I immerſed a frog in an atmoſphere of hydrogenous gas, he appeared not to ſuffer the leaſt inconvenience during the ſpace of thirty minutes, when being fully ſatisfied with what I had obſerved, coinciding with the experiments made upon frogs in water and mercury, I releaſed him. Theſe two laſt experiments were often repeated with the ſame reſult.

This laſt ſpring, I renewed ſome of the experiments upon frogs, eſpecially thoſe in which they were expoſed to the action of pure fixed air, and found that they were not capable of reſiſting its action ſo long a time as they did immediately before hibernation.

The firſt frog I immerſed in the ſpring, ſurvived the operation 9 minutes, but all the others did not ſurvive its effects 5, and ſome not two minutes and an half; whereas, in the fall they proved to be much leſs affected by the air, as they were ſometimes found to ſurvive 15 minutes, generally ten or twelve, and only one who had been expoſed to this air appeared to die in 8 minutes and an half, and his heart on diſſection had not loſt all irritability, and was diſtended with blood.

These experiments coincide with the idea held out in the note of page 28, and ſupport the doctrine of Girtanner relative to the accumulation of the irritability of animals and plants during the winter.*

Having

* By experiments inſtituted in the ſpring and Fall, may we not be able to aſcertain the relative quantity of irritability an animal gains during the period of hibernation.

HAVING eſtabliſhed that carbonic acid gas exerts a poſitive influence on inſects and amphibious animals, we ſhall next relate ſome experiments, to prove the ſame relative to quadrupeds.

I EXPOSED a mouſe to a factitious atmoſphere meaſuring twelve ounces and an half, the oxygenous gas of which was obtained from nitre by means of a gun barrel. That it was pure I now ſatisfied myſelf by the eudiometer.

AT firſt, upon ſubmerſion it appeared very uneaſy and ſtruggled much, but in the ſpace of a minute was bereft of all voluntary motion and fell down, exhibiting moſt of the ſymptoms already mentioned as occurring to animals when expoſed to fixed air: at the end of ten minutes it expired.*

* The purity of this atmoſphere, when tried in the eudiometer, by the teſt of nitrous air, after the animal had periſhed, appeared equal to that of the atmoſpheric air made uſe of in the following experiment, even allowing largely for the abſorption of carbonic acid gas by the water, which could not be great, as the nitrous air was poured in immediately after the admiſſion of the factitious atmoſphere,

ANOTHER ready to die with fear was immerſed in an equal quantity of atmoſpheric air; it continued to breath during an hour when I removed it, and put an end to its miſerable exiſtence. Another mouſe lived in an equal quantity of atmoſpheric air half an hour, when its breathing became a little laborious, and upon being removed returned immediately to its natural vigour, ſhewing its unconcern by eating.

I THINK it unneceſſary to relate any experiments which I have made upon birds, as thoſe which have been already mentioned, as inſtituted on inſects, amphibiæ and quadrupeds are ſufficient to eſtabliſh the fact we are in purſuit of. That fixed air does act on the inhabitants of the aërial regions, we learn from the poet * who ſays—

atmoſphere, and the diminution ſuffered to take place, which it did almoſt inſtantaneouſly, without agitating the two airs together, thereby avoiding, as much as the nature of the experiment would admit, all grounds of error.

* This has been conſidered as more properly applying to inflammable air, as fixed air could not riſe in the atmoſphere

" Spelunca alta fuit, vaſto immanis hiatu,
" Scrupea, tuta lacu nigro, nemorumque tenebris
" Quam ſuper haud ullæ poterunt impune volantes
" Tendere iter pennis; talis ſeſe halitus atris
" Faucibus effundens, ſupera ad convexa ferebat.*

We conclude this ſection, by declaring that which we are authoriſed, both by facts and experiments; viz. that carbonic acid gas does not produce its effects indirectly, by mechanically excluding atmoſpheric air from the lungs; but that it acts directly by an

moſphere on account of its gravity, but when mixed with atmoſpheric air, it will prove deſtructive to birds as well as other animals, as we ſee in the note juſt quoted from Morozzo, and when mixed in this way it will doubtleſs penetrate the air to a conſiderable diſtance above the place from which it is generated.

* Since writing the above, I have found a fact related by Morozzo, Journ. de Roſ. Vol. II. Ann. 1784, p. 114, which though tried in the inveſtigation of another point, tends directly to corroborate the opinion held out in this diſſertation. He ſays, " Dans tous les mélanges ou il y " avoit partie égale de gas déphlogiſtiqué, la durée de la " vie des animaux a été conſiderablement plus longue " que dans l'air atmoſphérique, ſi l'on excepte cependant " l'air vicie par la vapeur du charbon, dans lequel la vie " d'un moineau n'a été que de 24 minutes, et l'air fixe, " dans lequel elle a été de 38 minutes."

an inherent power on the animal œconomy, and particularly through the medium of the lungs.*

* We ſhould not be ſurpriſed that carbonic acid gas ſhould operate ſo hurtfully on the animal œconomy, when accumulated in too great quantity. Being generated in the ſyſtem, and conſtantly thrown out from the blood in the proceſs of reſpiration; may it not be looked upon as a fecal matter of the vaſcular ſyſtem? and, in this point of view, when accumulated there in exceſs; why ſhould it not prove as univerſally hurtful to the ſyſtem at large, as the preternatural retention of any other fecal excretions? It may be objected that the retention of fecal matters in general do not produce hurtful effects with ſuch great precipitation; but nature having ordained that a conſtant and complete evacuation of this gas ſhould be kept up from the blood, is it not perfectly agreeable to the dictates of ſound reaſon to ſuppoſe, that when this quantity is accumulated to any great degree, and in a rapid manner, that ill effects ſhould be produced thereby much more ſuddenly, than from the gradual accumulation of thoſe excretions to whoſe influence the animal œconomy is much more accuſtomed.

I have here conſidered the carbonic acid gas, which is diſcharged from the ſyſtem by reſpiration, as being generated in the blood, and not immediately by the combination of carbon and oxygenous gas in the veſicles of the lungs; for this obvious reaſon: any two ſubſtances, not actually under the influence of the animal œconomy, cannot enter into any combinations, otherwiſe than agreeably

WHAT the nature of this action of carbonic acid gas is, together with the moſt obvious methods of relieving its deſtructive effects, will be conſidered in the following ſection.

ably to the unerring dictates of the eſtabliſhed rules of chemiſtry. The oxygenous gas in reſpiration, cannot enter into any combination with carbon whilſt in the veſicles of the lungs, as it then may be conſidered as external to the influence of the ſyſtem, and the heat is not ſufficient to effect a combination; fixed air being produced only by a red heat. The cauſe of the formation of this air muſt, therefore, be referred to a law of the animal œconomy, which implies the combination to have taken place within the precincts of its organs. This opinion is further corroborated by our knowledge of the fact, that carbonic acid gas is diſcharged by the perſpiring pores.

Dr Ruſh in his lectures mentions a fact which puts this beyond the poſſibility of a doubt, viz. If in the morning a lighted candle is placed under the cloaths of a bed in which a perſon has lain all night, ſo great is the accumulation of this gas, that the flame is immediately extinguiſhed.

SEC-

SECTION III.

On what part of the general ſyſtem, and how does carbonic acid gas produce its effects?

Does it act more immediately upon the nervous ſyſtem? Or,

Is life affected more particularly by its operation on the blood and muſcular ſyſtem? And

Laſtly, What is the moſt obvious method of reſcuing animals from a ſtate of ſuſpended vital action, brought on by its noxious influence?

THAT carbonic acid gas makes ſome impreſſion on the nervous ſyſtem, cannot be denied; indeed the reſults of ſome of our experiments, the ſenſations, as related by the unfortunate Pilatre de Roſier,* with which he was affected immediately upon plunging into

* See Chaptal's Chemiſtry.

into an atmoſphere of that fluid, prepared by fermenting beer, and the analogous manner in which it affects our ſchniderian membrane* when diſengaged from our drink, all unite in teſtifying the truth of this poſition.

But although we hold that it acts in ſome meaſure upon the nervous ſyſtem, producing ſymptoms differing in violence according to its ſtrength, we are nevertheleſs far from imagining that all the direful conſequences reſulting to animals expoſed to its influence, ariſe from this action. An opinion embracing ſo much would doubtleſs far exceed the boundaries of truth, as is evinced by experiment; for, as has been before obſerved, animals will live a long time in fixed air, provided there is an ample flow of atmoſpheric air into the lungs.

It would be wrong here to paſs over in ſilence an experiment related by Landriani, which without ſtrict examination might appear to advocate the contrary doctrine. He obſerved that a fowl would die in a ſhort time, when confined in a bladder filled with carbonic

* It was ſuppoſed by a celebrated phyſiologiſt, that its principal ſeat of action was on this membrane.

nic acid gas, though the head was protruded out of the bladder: provided the edges were ſo ſecured round its neck by repeated ligatures that all communication between the external and internal air was cut off.

HOWEVER plauſible this may appear, we are diſpoſed to doubt, that death in this inſtance was produced by the operation of the carbonic acid gas on the external ſurface of the body, but truſt that it will not be wrong to attribute it ſolely to the preſſure of the ligatures round the neck; more eſpecially as the ſame experiment has been repeated, paying attention to this circumſtance without producing ſuch direful effects.

BEFORE I enter into the conſideration of the ſecond quere, it may be proper to premiſe ſome ideas reſpecting the blood.

THE intimate connection between muſcular action and vital air has long ſince been recorded by Fontana*, though from the ſtate of

* Fontana, vol. 2. p. 141-2, relates the following experiment.—"I pierced the fore-foot of a land turtle that

chemical knowledge at that time he could not be expected to give an ample and satisfactory history of the relationship. It has been since

" weighed a pound and an half, with an American arrow. " In eight minutes it could scarce move, and in a quarter " of an hour was dead. When the feet and neck were " stimulated, they discovered a slight degree of sensation. " Having opened the thorax I found the heart and au- " ricles quite motionless. I touched the heart, and it con- " tracted itself once each time. On freeing it from its " membranes, it began to move very briskly, and conti- " nued to do so for several hours. I covered it with the " inner shell, and in twenty-four hours found it again " motionless. I pricked it once with a needle, it con- " tracted a single time; I pricked it again, it contracted " afresh, and continued to do so once every time I pricked " it; I left it exposed to the air for three minutes, and it " then began to move of itself, continuing a very brisk " motion for several hours. I covered it afresh with the " shell, and on uncovering it in four hours after, found " it motionless. I left it in the air for a few minutes, and " in a short time, and of itself, it recovered its oscillations, " which continued for six hours. I again covered it with " the shell, and on uncovering it two hours after, " found it without motion. I then covered it with " water, which I kept on it for ten minutes, without " its producing any change. I drained off the water, and " the heart was scarcely left in the air a minute, when it " began to move briskly, and continued to do so for seve- " ral hours. Lastly, I put it in the sun, where it soon " dried. The auricles likewise dried in a degree, and all " was then still. I now wet both heart and auricles; the

" former

advanced (by Girtanner and Beddoes) that oxygenous gas, abſorbed during reſpiration is ſubſervient to the generation of irritability

" former continued always motionleſs, but the latter be-
" gan to move, and continued their motion for eighteen
" hours, when becoming dry they loſt it forever." The contractions here produced cannot be accounted for merely from the ſtimulus of the air, as, this being the caſe, they would have commenced immediately on contact with it, and at that time would have been the ſtrongeſt: Hence, it is evident, that the atmoſphere muſt have imparted ſome degree of irritability to the heart, which was neceſſary to be accumulated before the feeble ſtimulus of the air could excite motions.

This is further illuſtrated by an obſervation of Monſ. Troja. " Le cœur étoit pâle, et avec un forte irritation
" on excitoit a peine un légere irritabilité dans l'oreillette
" droite ſeulement: cependant, elle s'eſt manifeſtée davan-
" tage dans le ventricule droit, lorſque le cœur eut reſté
" quelque-temps expoſé à l'air." The count Morozzo obſerves, alſo, that when he opened ſparrows and rabbits who had periſhed in oxygenous gas their hearts exhibited marks of irritability a long time, the heart itſelf ceaſing to move ſpontaneouſly after two hours, but the auricles continued to move a conſiderable time longer. Theſe obſervations have the more weight as they were made by men of ſound underſtanding, and who held no theory on the ſubject by which they could poſſibly have been biaſſed. Girtanner relates the following experiment, which eſtabliſhes this idea without leaving a ſhadow of doubt. "A con-
" ſiderable quantity of very pure oxygene air was injected

in the animal œconomy; and that in ſome animals ſuch is the volatile nature of this irritability, that a conſtant ſupply is called for, to ſuſtain the functions of the different vital viſcera, whilſt in others, the tenacity of the moving powers for this principle is ſo great, that the neceſſity of ſo very conſtant and regular a ſupply is not ſo urgent. That this oxygenous gas when poured into the lungs by the ordinary efforts of reſpiration, is through their medium conveyed into the blood veſſels with which that viſcus copiouſly abounds,

" into the jugular vein of a dog. The animal raiſed moſt " terrible outcries, breathed very quickly, and with the " utmoſt difficulty; by little and little his limbs became " hard and ſtiff, he fell aſleep and died in leſs than three " minutes. Upon opening the thorax and the pericar- " dium, the heart was found more irritable than ordinary, " and its alternate contractions and dilatations continued " upwards of an hour. The right auricle of the heart " was vermillion, and it contained as well as the right " ventricle, a great quantity of blood of a bright vermilion " colour, frothy and not coagulated. The blood con- " tained in the left ventricle, in the aorta, and the arteries, " was of a roſe colour, and was mixed with bubbles of " air. All the muſcles were more irritable than ordinary. " After the blood contained in the heart and veins was " diſcharged, the irritability of the heart and the muſcles " ſenſibly diminiſhed."

abounds, and that uniting with the blood, it is thence conveyed, imparting heat and life even to the moſt remote parts of the body, ſo requiſite for the adequate performance of their functions. That it is by oxygene alone that the moving fibres are ſupplied with that irritability, ſo abſolutely neceſſary to their contractions; and that the production of this principle is wholly unconnected with the nervous ſyſtem*. So great is the validity of the facts advanced in ſupport of theſe opinions, that I have adopted them, as it is only by deducing reaſons from firm data, that ſpeculative reſearches can be of importance to true ſcience†.

DOES carbonic acid gas affect the blood?

* The functions of the nervous ſyſtem may be conſidered as wholly diſtinct from thoſe of the muſcular. The nerves are more particularly confined to ſenſation, and the muſcles to motion. The nerves ſerve to convey the electroid fluid as demonſtrated by Valli, &c. which acts as a ſtimulus, producing motion. The muſcles prepare the irritability from the blood without which the action of ſtimuli would be abortive.

† I muſt refer to Beddoes obſervations for a further detail of facts, &c.

Some experiments of Girtanner * would lead to the idea that its influence on blood was not great, for he allows it to poſſeſs no action on that contained in the arteries. But on the other hand he found, that its influence on venous blood was very great †, rendering the colour blacker than ordinary. Allowing that this poſition was juſt, even with reſpect to the action of this air on the blood in the animal œconomy, I attempted to account for its full effects.

Considering the arterial blood as imbibing oxygenous gas from the atmoſphere in reſpiration, and after having diſtributed this gas in the round of circulation, becoming venous and black on its arrival at the right ſide of the heart, it was evident, that when the communication between the lungs and vital air was cut off, that all the blood of the ſyſtem after one circulation would be entirely venous, and leave ample room for the carbonic acid gas to exert its moſt energetic influence.

One

* Beddoes Obſervations, 229.—Arterial blood from the carotid artery of a ſheep was received into a bottle filled with carbonic acid air, no change on the vermilion colour.

† Beddoes Obſervations, p. 243.

One very great difficulty however, ſtarted up againſt this opinion, and demanded, why carbonic acid gas inevitably produced the ſame effects, though in a ſlower degree, in the factitious atmoſphere, when there was ſufficient oxygenous gas, to render the blood in the lungs arterial, and to anſwer all the purpoſes of reſpiration?

It was to no purpoſe to explain away this objection, by imagining, that the ſlower effects were produced by the diluted ſtate of the carbonic acid air, and that this gas operated on the lungs by entirely excluding the abſorption of vital air, becauſe in this caſe animals in general would have periſhed in the factitious atmoſphere ſooner than they would have drowned, but this was not the caſe with quadrupeds. It was neceſſary then to hold that its operation was not confined ſolely to venous blood, but that it alſo had an immediate influence upon the blood of the arterial ſyſtem; throwing aſide the conſideration of any power that the arterial blood might poſſeſs, when out of the body, of reſiſting the action of fixed air, as no concluſive argument againſt its action on this blood in the living body,

body, and as not coincident with our knowledge of the animal œconomy, in which combinations and decompoſitions daily take place, which are not ſanctioned by external chemical affinities, but ſubject to the reigning laws of the animated organs*.

Is this action, whatever its nature and effects may be, dependant on the acidity of the carbonic acid gas, or muſt it be explained on other principles?

As the queſtion has been amply diſcuſſed by M. Troja, I ſhall relate two experiments which

* This laſt opinion I am the more inclined to adopt, as it accords with facts which cannot be entirely explained by the former. The following experiment related by Girtanner is conducive in ſtrengthening the probability of the latter hypotheſis. "A ſmall quantity of carbonic "acid gas was injected into the jugular vein of a dog. "The animal became ſleepy, and died in about a quarter "of an hour. The right auricle and ventricle of the "heart was filled with thick blood, and in part coagu-"lated. The blood contained in the left ventricle and "auricle was of a deeper colour than ordinary. The "heart and muſcles had loſt all their irritability." This I think proves, that the whole ſanguiferous ſyſtem can be affected by the carbonic acid gas,

which he made on the ſubject, preferring his own words, though all his ideas on the ſubject are not conſonant with our opinion.

" Mais la vapeur du charbon eſt elle nui-
" ſible par ſon acidité ? Par l'air phlogiſtiqué
" comme air phlogiſtiqué, ou par quelque
" autre principe dont elle eſt compoſée ?
" C'eſt un queſtion très difficile à diſcuter,
" et je la regarde ſupérieure à mes forces ;
" cependant, elle ne peut pas être meurtriere
" pour être ſimplement acide. Je deſirois
" avoir un moffette toute acide pour remar-
" quer ſéparément, et ſans compoſition d'au-
" tre ſubſtance, les effets qu'elle produiroit
" ſur les animaux. J'ai cru devoir me ſervir
" de l'air acide découvert par M. Prieſtley.
" A cet effet, je mis preſqu'une livre de ſel
" marin dans une grande cornue, et j'y
" verſai une bonne quantité d'huile de vitriol
" concentrée. Enſuite, je fis paſſer ſon gou-
" lot par un trou fait exprès, dans l'intéri-
" eur de ma grande caiſſe, en laiſſant ſon
" corps en dehors pour placer par deſſous une
" groſſe lumière.

" La

" La caiſſe fut remplie preſque dans l'in-
" ſtant de fumée, qui étoit l'air acide. J'y
" avois renfermé un chat. Il ſe porta très
" bien pendant quatres heures, à l'exception
" qu'il touſſoit de tems en tems par l'irritation
" de la vapeur dans le poumon : il rendit
" auſſi par la bouche une quantité prodigieuſe
" d'eau, en partie tres-fluide et limpide, et
" en partie comme le blanc d'œuf. Ennuyé
" de pourſuivre plus long-tems mon ope-
" ration, je mis en liberté l'animal. Il etoit
" un peu malade, verſoit de l'eau en grande
" quantité par la bouche, par le nez et touſ-
" ſoit fréquemment ; au bout de deux jours,
" il étoit bien remis.

" Si cette moffette n'avoit pas produit ſon
" effet avec la mort de l'animal, je ne pour-
" rois pas en accuſer l'abſence de l'air acide
" qui eſt immédiatement abſorbé par l'eau et
" par l'humidité : il en ſortoit toujours du
" nouveau de la cornue, dans laquelle j'avois
" remis pluſieurs fois du ſel et de l'huile de vi-
" triol, et la caiſſe avoit été toujours remplie
" de fumée. La quantité de cet air etoit ſi
" conſiderable, qu'elle avoit trempé, ſous

" forme

" forme d'eſprit de ſel marin, tous les parois " de la caiſſe, pénétré la ſubſtance du bois " même, s'étoit fait jour à travers quelques " commiſſures des planches qui étoient cal- " feutrées avec du papier et de la colle, et a- " voit tout mouillé le corps de l'animal.

" CEPENDANT, je n'avois pas accompli " le but de mon expérience. Je calfeutrai " mieux les commiſſures de la caiſſe ; et je " recommençai la meme opération et j'y ren- " fermai un gros chien. Je fournis de l'air " acide pendant quatre heures, j'en eus " préciſément le même reſultat. Alors, j'otai " le feu de deſſous la cornue, et je laiſſai le " chien renfermé juſqu'au lendemain matin. " Il y reſta 14 heures. Quand j'ouvris la " caiſſe, l'odeur acide étoit ſi forte, que mes " dents s'en reſſentirent toute la journée. Je " m'attendois à trouver l'animal preſqu'ex- " pirant ; ſi ce n'eſt, diſois-je, la vapeur " acide qui l'a maltraité, ce ſera la moffette " excitée par ſa reſpiration : point de tout, il " ſe portoit très-bien, et il me paroiſſoit me- " me plus vigoureux." Thus it appears, that it

it is not by its acidity that carbonic acid gas acts.

WHENCE, then, do these effects proceed?

I WILL hazard a conjecture on the subject, though it may hereafter be found far from coinciding with the fact.

I SUPPOSE an inherent property* in carbonic acid gas, inducing when combined in too great quantity with the blood, whether arterial or not, such changes in its nature, as to banish from its dominions all oxygenous gas, according to its state of concentration; causing it to combine with the moving parts of the animal œconomy to which it is more particularly destined, thereby producing a great accumulation of excitability, which when acted on by the ordinary stimuli then existing in the system, produces all the phenomena incident to submersion in that fluid.†

* Probably its stimulating property.

† It may possibly act only indirectly on the blood, by exhausting the irritability of the muscles, thereby causing a rapid demand for the oxygenous principle which would be

This view of the ſubject enables us to account, in a ſatisfactory manner, for the ſymptoms which have been related as taking place, whilſt the animal was alive, during the time of ſubmerſion in carbonic acid gas.

It has been obſerved that the heat of animals, whoſe vital action has been ſuſpended by carbonic acid gas is conſiderably encreaſed. This Phenomenon I conceive cannot be accounted for, unleſs from the ſudden converſion of oxygenous gas, exiſting in the blood, into the principle of irritability or at leaſt into a ſtate of combination with the ſolids; and the more than ordinary black colour of the blood, from the entire expulſion of oxygenous gas from that fluid.

The encreaſed action of the heart and arteries during the firſt ſtage of ſubmerſion, may be explained ſatisfactorily from the rapid generation of irritability, and the continued action of the various ſtimuli upon it; as

be conſequently exhauſted from that fluid; or there may be a compound action, as it may act both directly and indirectly.

as well as the ſubſequent feebleneſs, fluttering, and total decline, from its as rapid decay.

ANY further enlargement on this hypotheſis would render the length of this diſſertation unuſual, I ſhall therefore, leave it thus but imperfectly ſketched to the judgment of the candid.*

* It has been already obſerved that the carbonic acid gas was conſidered as an excretion, and that it was formed in the blood veſſels by the combination of oxygenous gas with carbon. It ſeems to have been intended by the all beneficent hand of nature that this excretion ſhould not be formed and evacuated in vain, for agreeably to our hypotheſis, it muſt act as a balance to the ſyſtem, in great meaſure curbing, in common circumſtances, the immoderate accumulation of excitability, ſo often productive of dreadful conſequences.

When oxygenous gas is poured into the ſyſtem in exceſſive quantities, carbonic acid gas is thereby more abundantly generated, and thence acts on the blood &c. leſſening the influence of the oxygene, keeping the ſyſtem in great meaſure at the natural ſtandard: on the other hand, when the quantity of oxygenous gas is deficient, the production of carbonic acid gas is conſequently diminiſhed, and its action on the blood is therefore more reſtricted, keeping in a negative manner, the ſources of irritability from falling too low. Nevertheleſs, there

doubt-

WHAT is the moſt ſucceſsful method of relieving animals, whoſe vital functions are ſuſpended by carbonic acid gas?

FROM the various obſervations which I have made, reſpecting the diſeaſed ſtate induced by carbonic acid gas, I am inclined to believe that the effects produced by it are much more ſerious in their nature than thoſe ariſing from ſubmerſion in water; nor am I ſingular in this opinion. M. Troja who made many ingenious experiments on the ſubject in the year 1778, and whoſe name has often appeared in the courſe of this enquiry held the ſame opinion. The reaſons, however, which ſeem to have induced him in a great meaſure to adopt this idea, I muſt confeſs, are ſuch as do not point out to me the propriety of the opinion, not that I think they would be without weight, did the facts from which they are adduced really exiſt*.

doubtleſs are caſes wherein by the exceſſive quantity, or by deficiency of oxygenous gas, this equipoiſing quality of the carbonic excretion cannot be of the leaſt avail, when highly morbid effects are thereby inevitably induced.

* What we allude to here more particularly is, the idea which he held concerning the rupture of the lungs, which he

The want of authenticity, nevertheleſs, of his facts, cannot materially affect the doctrine, provided more ſubſtantial proofs can be marſhalled in its ſupport.

THE following comparative experiments were inſtituted to determine the juſtneſs of this hypotheſis.

I IMMERSED a mouſe under a receiver of water, and ſuffered it to remain until no motion was to be obſerved, except very faint movements of the heart.

AT the ſame time, I immerſed another mouſe of equal vigor, under a receiver containing 7 oz. of the factitious atmoſphere, and did not remove him until he had become much

he imagined invariably took place in animals who had periſhed in carbonic acid gas. I could never obſerve, that any rupture had intervened in theſe caſes, though I repeated his experiment ſeveral times, except in one caſe in which by a careleſſneſs in diſſecting, my knife had effected an artificial aperture. His experiments in attempting recovery after the pulſe had ſtopped, was a further inducement; but we have facts which evince, that ſo general an induction as he draws from his experiments in our preſent ſtate of knowledge, would be not only very unjuſt but inhuman.

much enfeebled, his reſpiration at conſiderable intervals, and the movements of the heart, irregular and frequent.

Upon removing the mouſe which had been ſubmerſed in water, into the air, it lay a ſhort time without making any efforts to breathe, and without any ſign of remaining irritability, beſides the ſlight motion of the heart already mentioned; however, in the ſpace of forty ſeconds, or a minute, ſome ſlight ſtrugglings occurred, a ſpontaneous breathing commenced, and it recovered in a ſhort time ſo far as to crawl, when I put an end to its ſufferings.

The latter mouſe, though it ſtill continued to reſpire after I had removed it into the atmoſpheric air, did not recover from its ſtupid ſtate, all the efforts in reſpiration were to no purpoſe, and it ceaſed to live in the ſpace of five minutes. No endeavours were made to expedite the recovery of either.

A dog alſo, who had been expoſed to carbonic acid gas, expired after he had been removed

moved from its influence, though he breathed three times, after he had been conveyed to the atmospheric air. In this case I made no efforts to recover the animal*.

THOUGH candour forbids that I should omit giving my sentiments on this delicate point, I am far from wishing in the least to influence the practical exertions of any man, and whatever may be my opinion, I think it highly criminal, not to seize upon with avidity every opportunity of being of service to our fellow creatures, who have suffered in this way as well as in any other. There is always a possibility† of effecting a recovery, even where appearances have advanced further than in the cases already mentioned, before succour has been afforded ‡; thus

* Percival relates a case which he quotes from the Epistles of Donatus, of two boys, where the pulsation continued after they had been exposed to the fumes of charcoal; they died.

† Troja thinks otherwise, hence the dangerous tendency of his hypothesis.

‡ This is evinced in the case of M. L'Abbé Briquet, whose vital functions were completely suspended by the fumes of charcoal, and still he recovered. Vid. Ros. Journ. 1774. vol. 2. p. 464.

thus no exertions ſhould be ſpared to ſecure the moſt trifling advantages to the patient, howſoever deſperate the caſe may appear, whilſt at the ſame time, we ſhould be ever upon the guard, not to be too much flattered by appearances, leſt we give riſe to hopes which the true ſtate of the matter will not admit of.

THE remedies which our view of the ſubject, and the experience of many will allow us to make uſe of are but few.

OUR firſt endeavours, however, ſhould be directed to remove the patient from the noxious cauſe. Here too many cautions cannot be inculcated, againſt entering places in which animals have periſhed, leſt by raſhly obeying the dictates of a blind, though laudable humanity we are haſtily precipitated into the ſame deplorable ſituation, from which it was our ardent deſire to reſcue a fellow mortal.

IT has latterly been generally deemed ſafe to truſt our lives in places which are confined, provided there was a ſufficient quantity of oxygene gas to ſupport flame.

If the extinction of flame, and of animal life, depended upon the same principles, this idea would be just, but as flame can subsist as long as there is vital air to support it *, and it has been proven already that this is not the case with animal life, the hypothesis cannot be just, and some more effectual tests should be resorted to before we decide on the event. Lime water is the best test to ascertain the presence of fixed air, but to be certain that no evil consequences will ensue, it will be necessary to try its effects first upon some animal less valuable than man.

In cases when we are not certain of the length of time taken to produce the morbid effects, it may be proper to use the above precautions, before we attempt to afford relief; but when we know that the effects have been sudden and violent, the fact itself evinces the dangerous consequences of exposing ourselves to its influence, and then the patient must

* I prepared a factitious atmosphere as before, and found that a candle burned in it with great lustre and rapidity until almost all the vital air was consumed. Morozzo found that a candle burned very vigorously in the oxygenous gas, in which many animals had perished.

muſt be withdrawn with hooks and other convenient implements beſt calculated to be ſucceſsful, at the ſame time offering as little into the body as poſſible.

When the patient is perfectly under our command the following method ought to be purſued as it has oftenest been crowned with ſucceſs.

Having obtained a thorough command over the body, we are as quickly as poſſible to expoſe it to a full current of air. In theſe caſes very little aſſiſtance is wanted, and we muſt not permit unoccupied perſons to remain, as they would only contaminate the ſlender portion of oxygenous gas, which ought to be carefully huſbanded, for the uſe of the unfortunate patient.

If circumſtances will not admit of moving the patient to an airy ſituation, we muſt by artificial means, endeavour to render the place of neceſſity, as eligible as poſſible by agitating the ſurrounding air and blowing upon the body with large fans, &c. In the mean time, however,

however, we ſhould be preparing to inflate the lungs with oxygenous gas, if it can be procured, without delay; but, if not, with the common atmoſpheric air, not neglecting repeatedly to daſh cold water over the face and body of the patient; ice may be applied with advantage when very cold water is not at hand.

In many caſes aſſiſtance is afforded ſo ſoon as to preclude the neceſſity of reſorting to inflations, as when the reſpiration is not quite arreſted, here we may only employ the cold bathing and ventilations with advantage.

Blood letting, which was inſtituted in former days under a falſe idea of the cauſe of the evil (that it aroſe from apoplexy) is not adviſeable, as the quality of the remaining blood, as reſpects the noxious cauſe, cannot be changed by this means.

The promiſcuous uſe of ſtimulating remedies of all kinds, operate in a direct line with thoſe which precipitated the cataſtrophe, and are therefore hurtful*.

The

* Troja, Journ. Roſ. an. 1778. vol. 1. p. 485.

The uſe of inflating the lungs cannot be doubted by the moſt ſceptical, for it is only by reſtoring the proper quantity of oxygenous gas to the blood and muſcular ſyſtem that life can again evolve its various functions.

The indication of repeated ablutions with cold water, is not quite ſo obvious. The frequent ſervices * it has rendered to animals ſuffering from the effects of fixed air, have eſtabliſhed it as a remedy of the utmoſt importance, but the ratio operandi, however, as yet, has been involved in a degree of obſcurity.

It

* "Un cuiſinier de Nancy, ſuffoqué par la vapeur "du charbon, et reſuſcité par l'aſperſion de l'eau fraiche. "Journ. de Roſier, 1775, Vol. I. p. 31.

The caſe of M. L'abbe Briquet de Lavaux—Ros: Journal, wherein it is related by M. Banau, M. D. "M. "L'Abbé de Lavaux étoit abſolument ſans pouls et ſans "reſpiration, ſon viſage très-rouge et bouffi, ſes yeux "ſaillans. Il ne donnoit aucune marque de vie, et ſi l'on "en excepte la putrefaction, il avoit tout les ſignes de "la mort."

He was recovered principally by the uſe of cold water, and a great current of cold air. The only animals which I ſucceeded in recovering, were ſuch as were treated by inflations and cold bathing.

It may, however, be remembered that an increaſe of heat was obſervable in animals who were deprived for a time of vital action by this deſtructive gas. The cold water here ſteps in to reduce that, and to bring the whole ſyſtem to ſuch a ſtate (I may call it a ſtate of temporary hybernation) in which by the ſuſpenſion of all ſtimuli, the irritability of the body will have time to accumulate, and then the gradual application of natural ſtimuli will regulate the motions of the ſyſtem, and finally reſtore order and tranquility.

The remedies after the body has emerged from imminent danger, muſt be applied according to the ſtate of the ſyſtem and the varying nature of the preſent circumſtances.

As the *neceſſity* of writing, alone could have prompted me thus early to have appeared in the literary world, I muſt beg the indulgence of the critic, the man of candour and generoſity will offer it ſpontaneouſly.

THE END.